Development of a high stability L-band radiometer for ocean salinity measurements

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Ultra Stable Microwave Radiometer

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- **Future Sea Surface Salinity (SSS) missions will require SSS measurements with accuracy of 0.1 psu and with spatial resolutions < 50 km**
- **Goal: Develop L-band radiometers to have calibration stabilities of ≤ 0.05 K over 2 days**
- **This is a factor of 10 improvement over current spaceborne radiometers**

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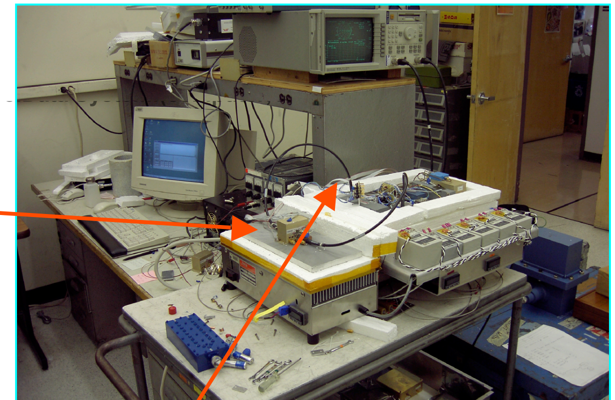
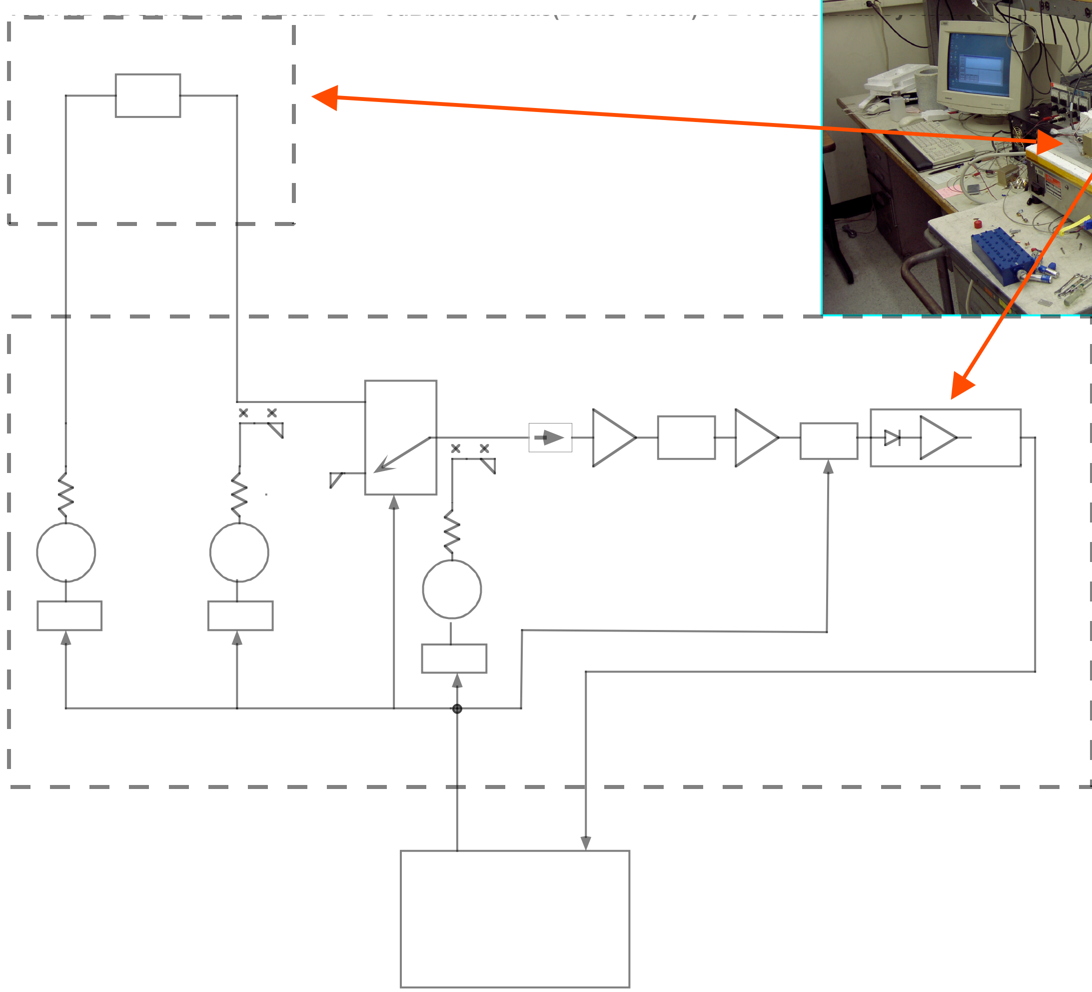
JPL Laboratory Testbed





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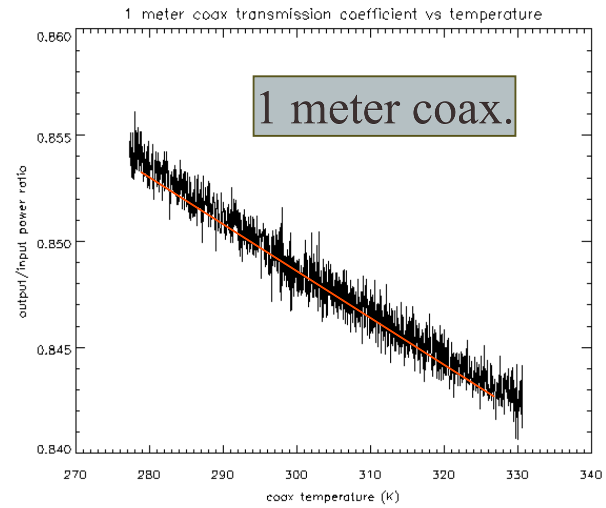
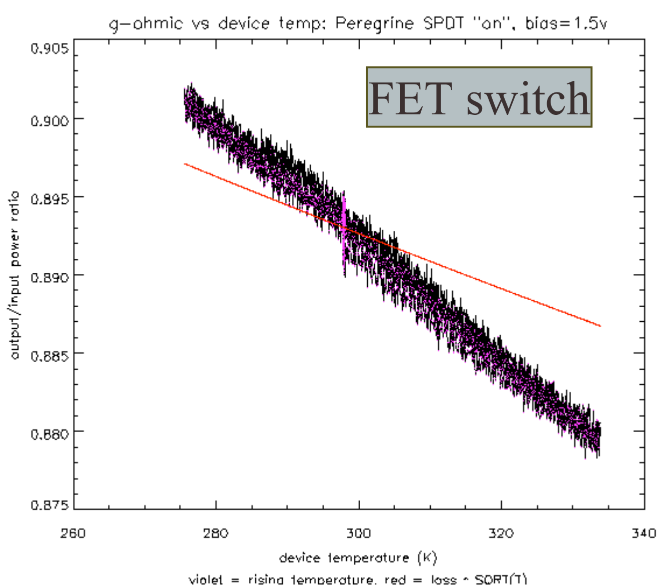
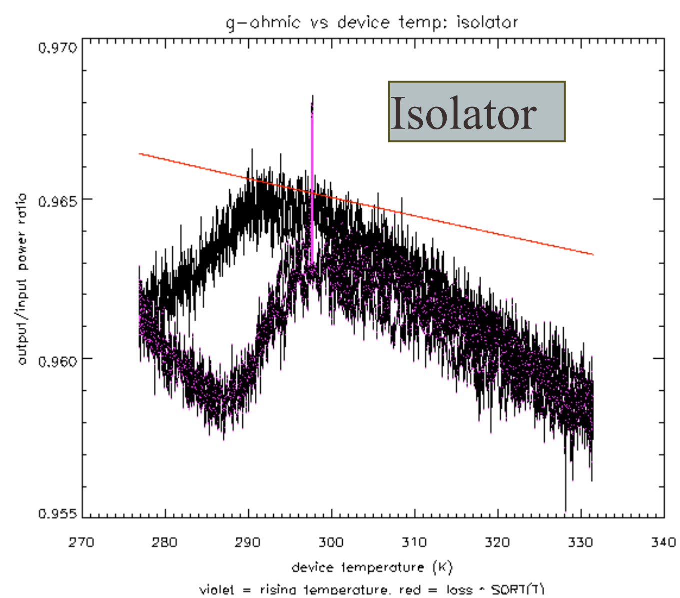
Component loss measurements

(plotted as ‘gain’ = output/input ratio)

Red lines represent trend predicted by copper conductivity: $1 - g \propto \sqrt{T_D}$







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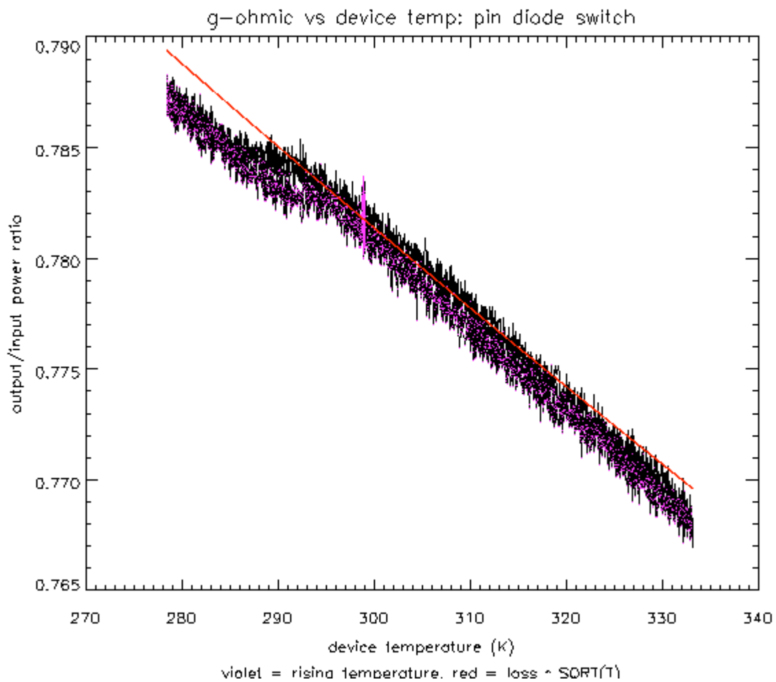
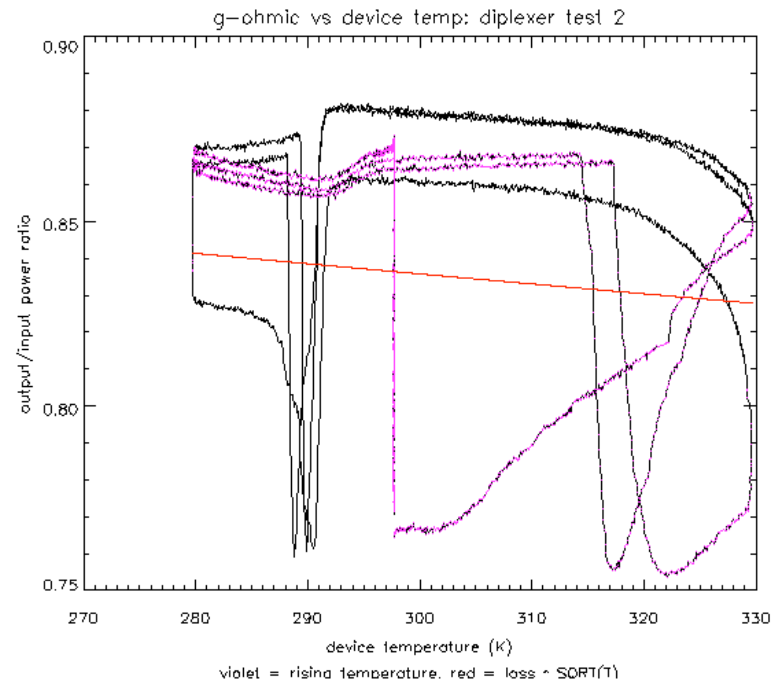
Component loss measurements (con't)

PIN diode switch



Frequency Diplexer



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Calibration algorithm to optimize NEDT with maximum stability:

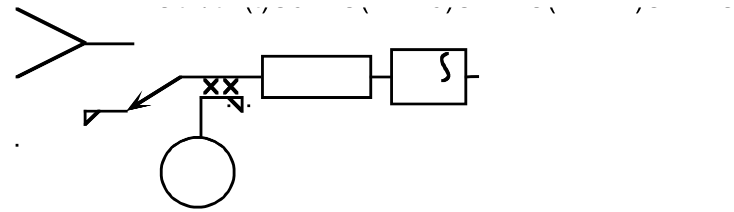
- New calibration scheme uses the fact that receiver noise temperature (T_r) is very stable.
- NEDT for an antenna observation optimized by forming separate running averages of gain and receiver noise.
- Optimization parameters are:

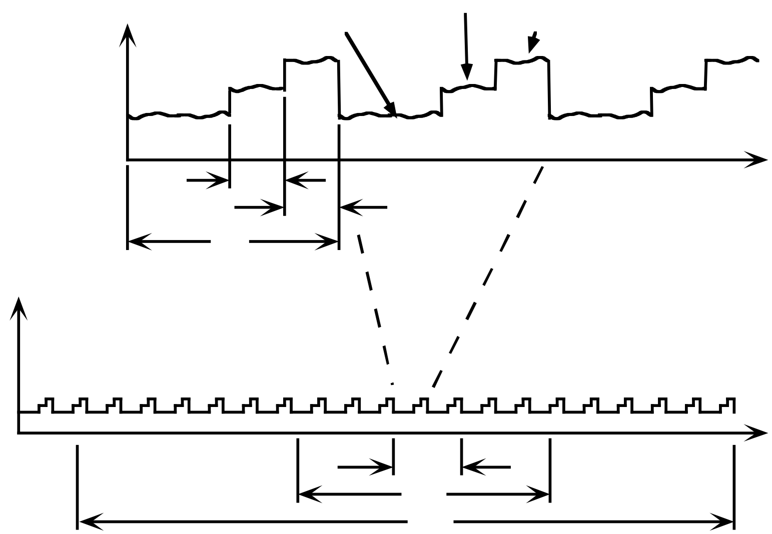
τ_g: gain estimation integration time

τ_r: receiver noise estimation integration time

d_o: reference load duty cycle

d_N: noise diode duty cycle





- Calibration formula:

$$T_A = C_A G^{-1} - T_r$$

τ_A τ_g τ_r

$$G^{-1} = \left(d_o \frac{T_o + T_r}{C_o} + d_n \frac{T_o + T_{ND} + T_r}{C_N} \right) \frac{1}{d_o + d_N}$$

$$T_r = C_o \frac{T_{ND}}{C_N - C_O} - T_o$$

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Calibration algorithm to reduce NEDT (cont.)

Model of gain and receiver noise spectra:

$$S(G) = a_g + \frac{b_g}{f} \qquad (\mathrm{Hz}^{-1})$$

$$S(T_r) = a_r + \frac{b_r}{f} \qquad (\mathrm{K}^2/\mathrm{Hz})$$

a=white noise (depends on B, τ, d)

b= fit to measurements

Optimization results:

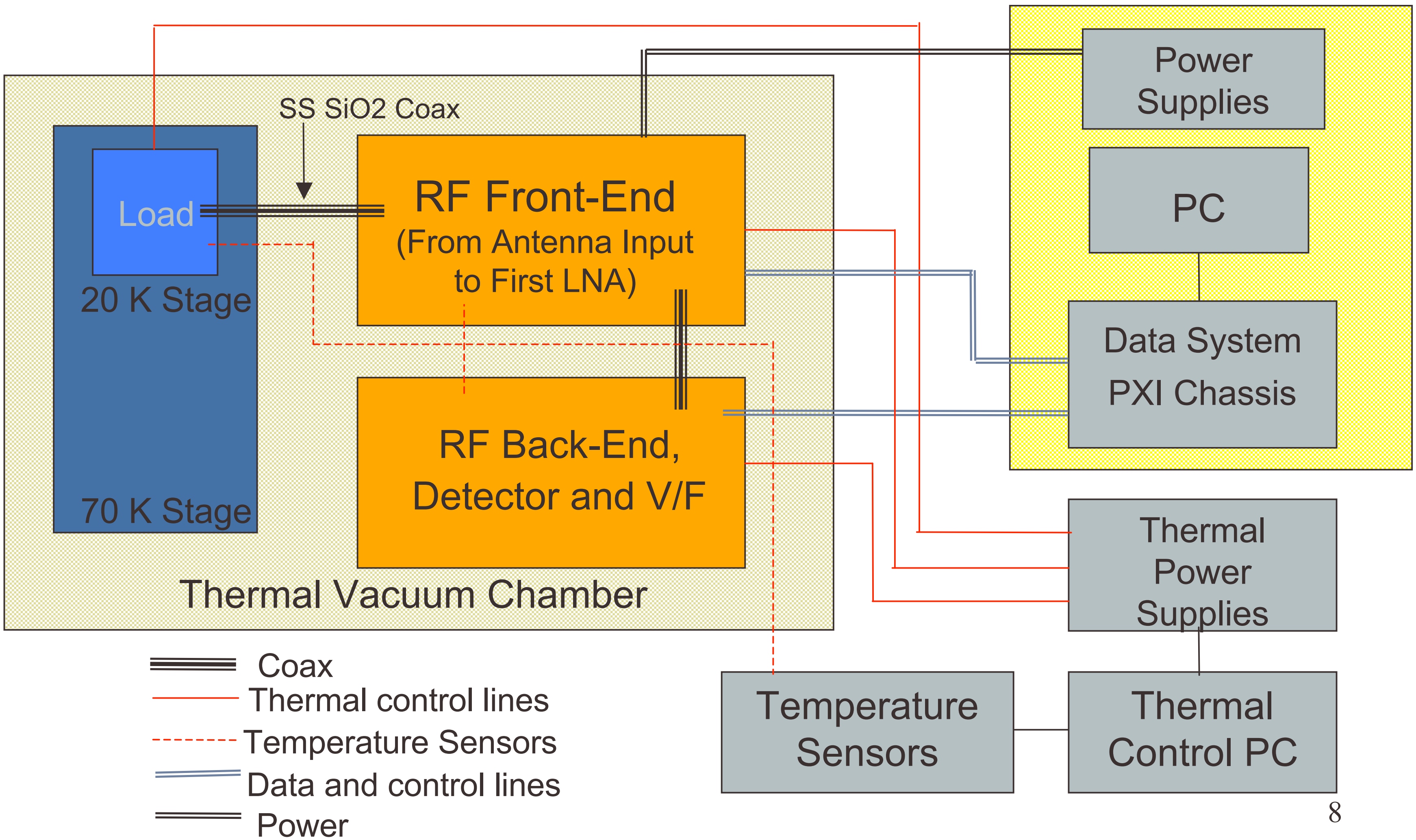
System parameters:					
			τ_A=12 s b_r=6.5x10^{-6} K^2/Hz b_g=2.0x10^{-9} /Hz T_r=255 K T_o=295 K T_{ND}=500 K T_A=100 K B=20 MHz		
τ_r (s)	τ_g (s)	d_o	d_N	NEDT (K)	$/\Delta T_{TP}$*
555630	96	0.24	0.02	.0375	1.64
157812	96	**0.13**	**0.13**	.0376	1.64
5000	86	0.19	0.10	.0381	1.66
5000	89	**0.14**	**0.14**	.0382	1.67
1000	71	0.23	0.12	.0401	1.75
1000	69	**0.18**	**0.18**	.0403	1.76

notes: **highlighted** indicates constrained parameter

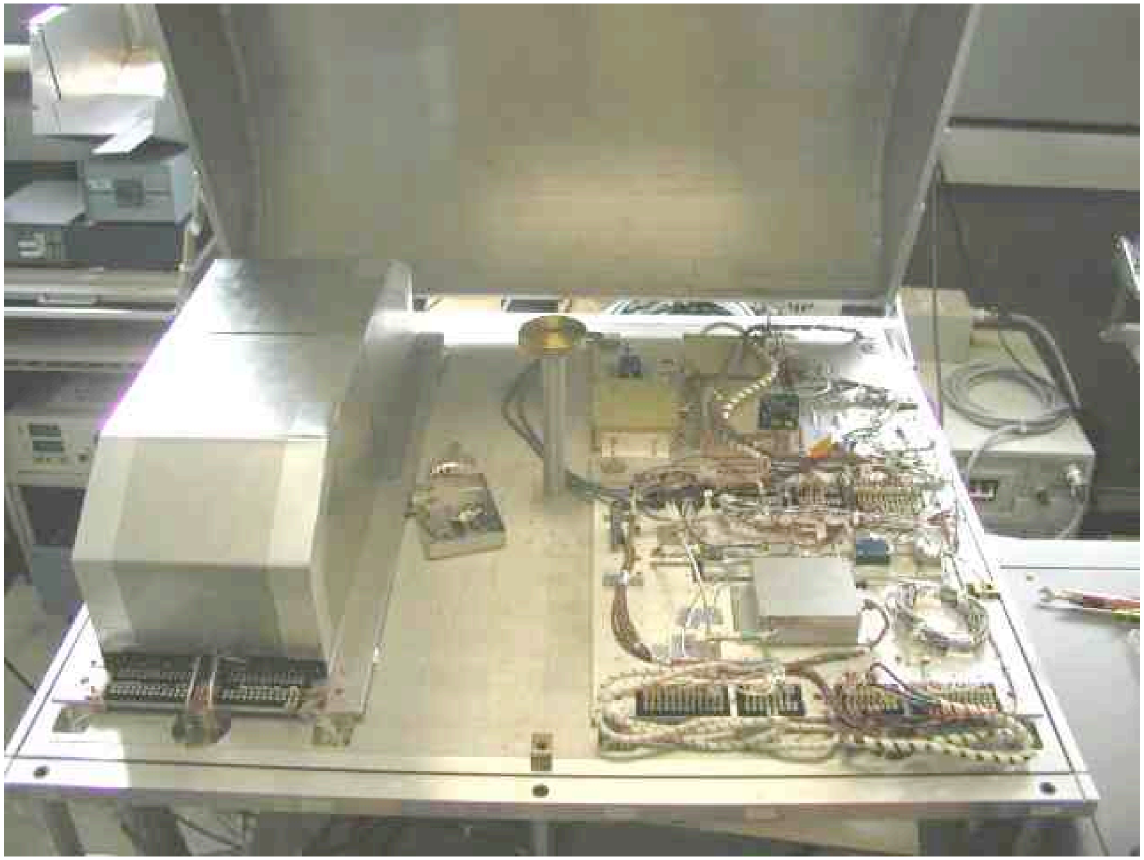
*

$$\Delta T_{TP} = \frac{T_r + T_A}{\sqrt{B\tau_A}}$$

GSFC Radiometer Test Setup

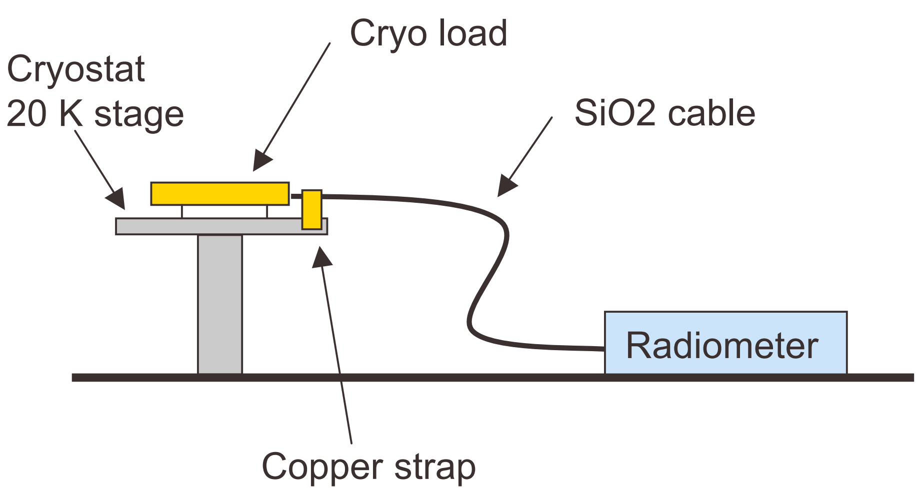


GSFC Radiometer Test Setup

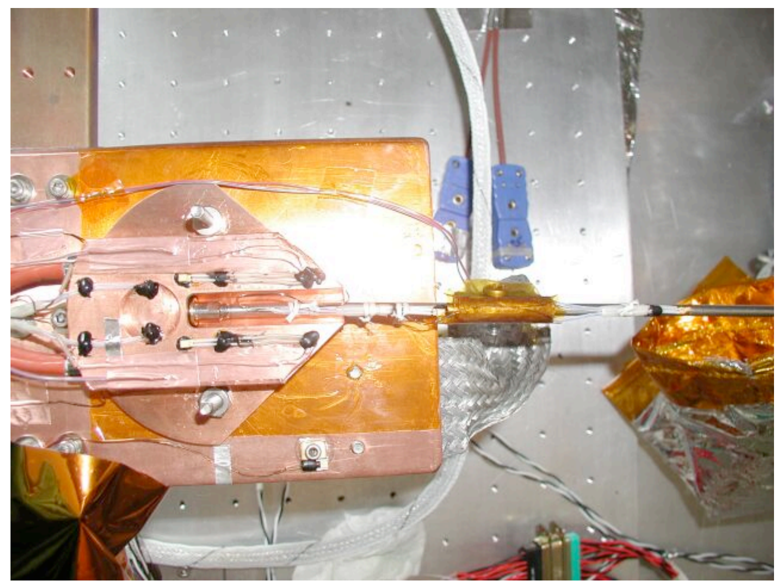


Input Load Temperature Distribution

- Temperature distribution is not a simple linear relationship.
- Ran several tests with temperature sensors located in different regions of the cable and at different load temperatures to determine optimum sensor locations.

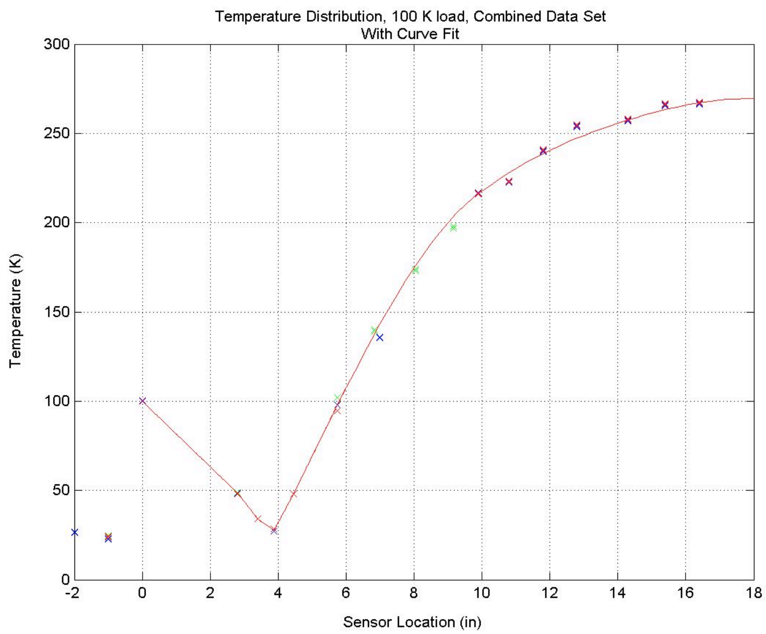


Cryogenic load Close-up

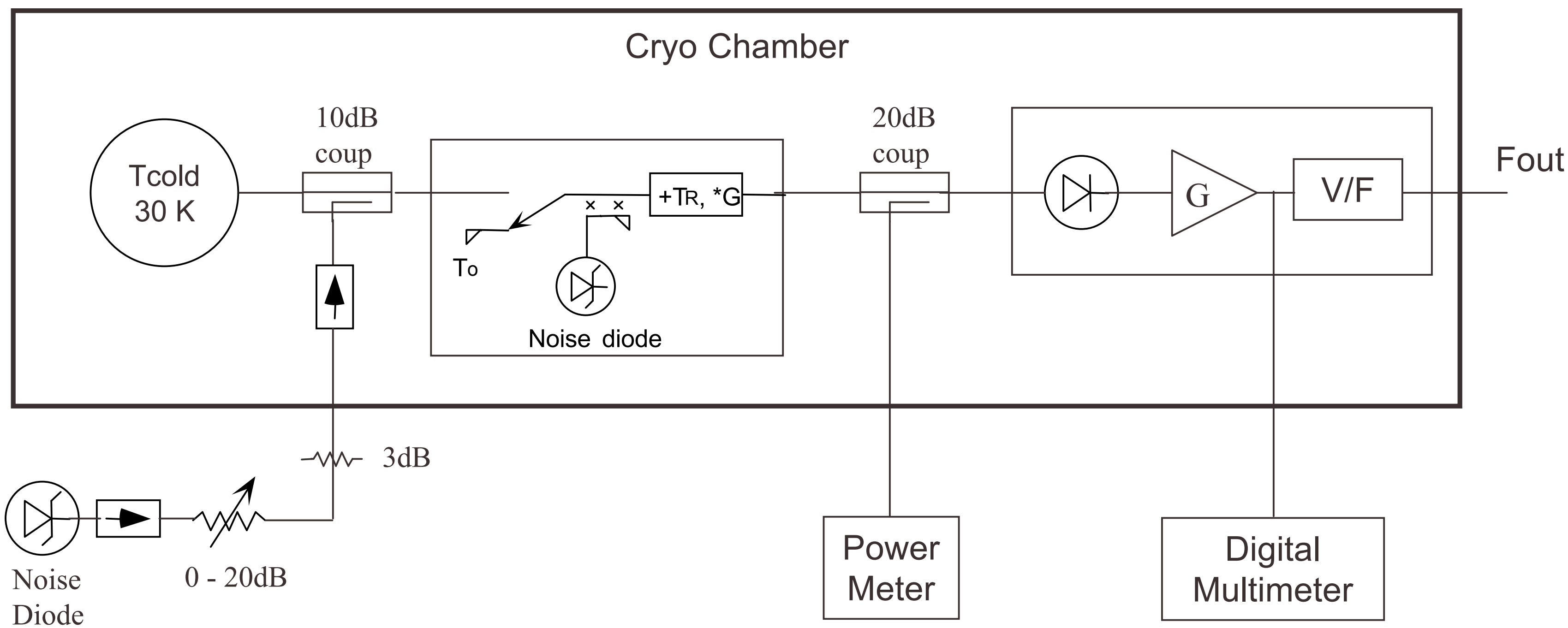


Input Load Temperature Distribution

- Created a model for cable losses based on the temperature distribution, connector losses and mismatches.
- A sensitivity analysis to these parameters suggests that the input to the radiometer can be stable with an uncertainty of ~0.03 K rss.



Linearity Test Setup



System Linearity

- Linearity measured with noise diode deflections:

$$\frac{V_{AN} - V_{A}}{V_{ON} - V_{O}} = 1$$

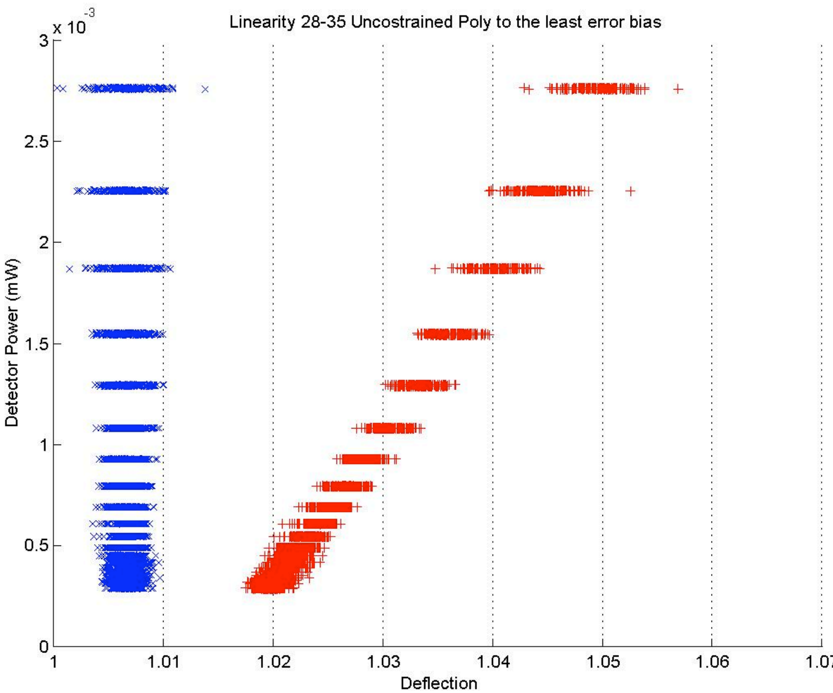
- Test setup allows characterization at the system level without any changes in the RF or video circuitry.
- Can test over a wide dynamic range covering well above and below the expected ocean temperatures.

Tin (K)	Detector Power (dBm)
4700	-25
30	-35.8

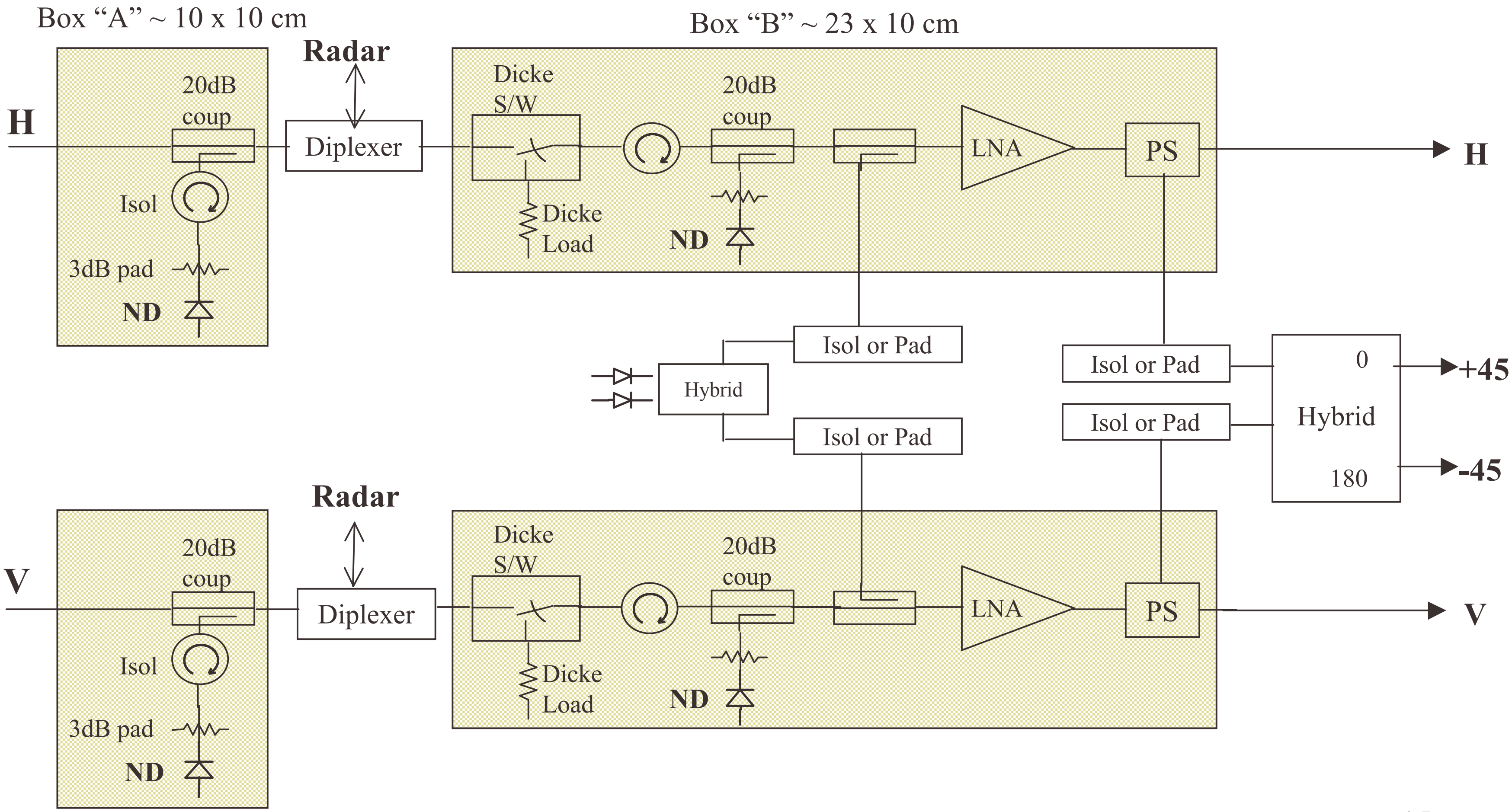
System Linearity (cont.)

- System appears to have a gain expansion behavior, as expected of the detectors, and gain compression at the higher levels.

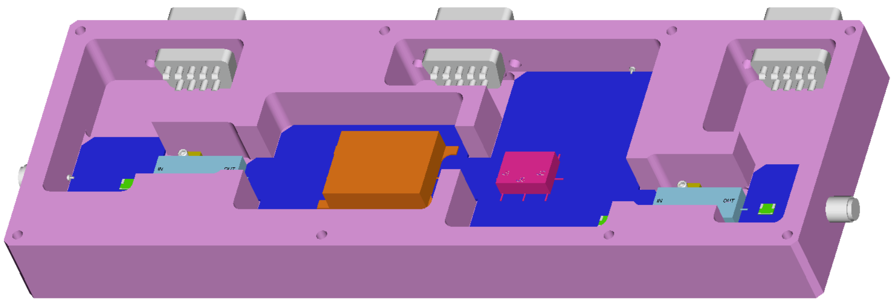
- Best linearization results were obtained with a 3rd order polynomial.
- The linearity was better than 0.02%

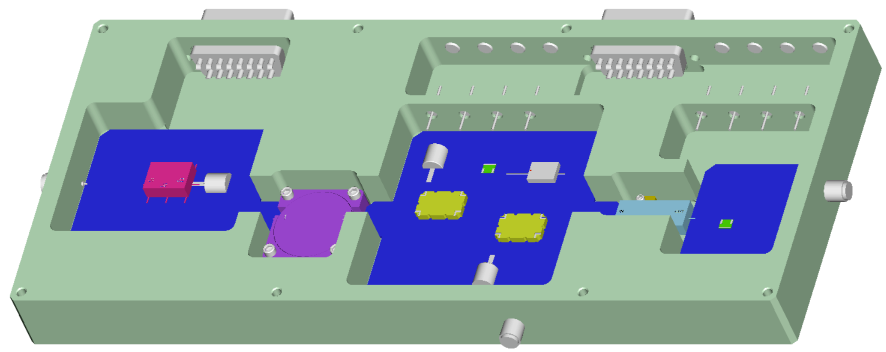


Radiometer Front-End Configuration



GFSC MIC Ultra Stable Radiometer





Summary

- Careful temperature control of the critical radiometer components, makes it possible to achieve excellent calibration stabilities
- Analytical expressions are being developed to optimize the observing switch sequence which will significantly reduce the NEDT
- A linearity test procedure was developed to accurately measure the non-linearity and then correct the data
- The Aquarius MIC radiometer prototype is being developed and will be tested in the GSFC testbed